AD-A235 342

REPORT DOCUMENTATION PAGE

Form Approved OMB No. 0704-0188

1a. REPORT SECURITY CLASSIFICATION: Unclassified

1b. RESTRICTIVE MARKINGS:

2a. SECURITY CLASSIFICATION AUTHORITY:

2b. DECLASSIFICATION/DOWNGRADING SCHEDULE:

3. DISTRIBUTION/AVAILABILITY OF REPORT: Approved for public release; Distribution unlimited

4. PERFORMING ORGANIZATION REPORT NUMBER(S): PL-TR-91-2089

5. MONITORING ORGANIZATION REPORT NUMBER(S):

6a. NAME OF PERFORMING ORGANIZATION: Phillips Lab, Geophysics Directorate

6b. OFFICE SYMBOL (If applicable): PHG

7a. NAME OF MONITORING ORGANIZATION:

6c. ADDRESS (City, State, and ZIP Code): Hanscom AFB Massachusetts 01731-5000

7b. ADDRESS (City, State, and ZIP Code):

8a. NAME OF FUNDING/SPONSORING ORGANIZATION:

8b. OFFICE SYMBOL (If applicable):

9. PROCUREMENT INSTRUMENT IDENTIFICATION NUMBER:

8c. ADDRESS (City, State, and ZIP Code):

10. SOURCE OF FUNDING NUMBERS

PROGRAM ELEMENT NO.	PROJECT NO.	TASK NO.	WORK UNIT ACCESSION NO.
61102F	2311	G4	01

11. TITLE (Include Security Classification): The Effect of Solar Activity on the Cosmic Ray Intensity at Solar Minimum

12. PERSONAL AUTHOR(S): M.A. Shea, D.F. Smart

13a. TYPE OF REPORT: Reprint

13b. TIME COVERED: FROM ______ TO ______

14. DATE OF REPORT (Year, Month, Day): 1991 April 29

15. PAGE COUNT: 4

16. SUPPLEMENTARY NOTATION: Reprinted from 21st International Cosmic Ray Conference, Conference Papers, 6 13-17, 1990

17. COSATI CODES

FIELD	GROUP	SUB-GROUP

18. SUBJECT TERMS (Continue on reverse if necessary and identify by block number): Cosmic rays, Solar activity, Solar cycle

19. ABSTRACT (Continue on reverse if necessary and identify by block number)

In examining the cosmic ray intensity between successive solar minima, it has been noted that the intensity at 1 AU was slightly higher between the 19th and 20th solar cycles (i.e. 1965) and between the 21st and 22nd solar cycles (i.e. 1987) than between the 20th and 21st solar cycles (i.e. 1976). The fact that the galactic cosmic ray intensity in the mid 70's did not return to the levels observed at the other two solar minima is attributed to increased solar activity throughout the 1976 solar minimum period.

20. DISTRIBUTION/AVAILABILITY OF ABSTRACT: ☐ UNCLASSIFIED/UNLIMITED ☒ SAME AS RPT. ☐ DTIC USERS

21. ABSTRACT SECURITY CLASSIFICATION: Unclassified

22a. NAME OF RESPONSIBLE INDIVIDUAL: M.A. Shea

22b. TELEPHONE (Include Area Code): (617)377-3977

22c. OFFICE SYMBOL: PHG

DD Form 1473, JUN 86 — Previous editions are obsolete.

SECURITY CLASSIFICATION OF THIS PAGE: Unclassified

PL-TR-91-2089

Reprint from 21st International Cosmic Ray Conference, Conference Papers, 6, 13-17, 1990.

THE EFFECT OF SOLAR ACTIVITY ON THE COSMIC RAY INTENSITY AT SOLAR MINIMUM

M. A. Shea and D. F. Smart

Geophysics Laboratory, Hanscom AFB, Bedford, MA 01731 USA

Abstract

In examining the cosmic ray intensity between successive solar minima, it has been noted that the intensity at 1 AU was slightly higher between the 19th and 20th solar cycles (i.e. 1965) and between the 21st and 22nd solar cycles (i.e. 1987) than between the 20th and 21st solar cycles (i.e. 1976). The fact that the galactic cosmic ray intensity in the mid 70's did not return to the levels observed at the other two solar minima is attributed to increased solar activity throughout the 1976 solar minimum period.

Introduction. The cosmic radiation intensity has been continuously measured by neutron monitors since 1953. Changes in the cosmic radiation intensity as a function of solar cycle have long been recognized with the maximum intensity occurring approximately seven months after sunspot minimum as defined by the smoothed sunspot number. During the 19th solar cycle, cosmic ray studies were concentrated on the large Forbush decreases that occurred during and after the IGY, and the 20% solar cycle variation that was measured by high latitude monitors between 1954 and 1959. Interest in solar cycle variations was renewed in the 1970's with the detection of an unanticipated and rapid recovery of the cosmic ray intensity after the solar activity maximum of the 20th solar cycle and the "square wave" shape of the cosmic radiation intensity curve between 1971 and 1978. This phenomenon gave rise to arguments related to 22-year cycles and the importance of drifts in the modulation of cosmic radiation. One point that appears to have been ignored in the various discussions related to the overall solar cycle changes in the cosmic radiation intensity is the fact that the galactic intensity measured between the 20th and 21st solar cycles did not reach the same solar minimum value as detected between the 19th and 20th cycles and the 21st and 22nd cycles. We suggest that this effect may have been related to increased solar activity throughout this solar minimum period.

Definition of Solar Minimum. Solar minimum is usually identified as the month where the smoothed sunspot number reaches its minimum value between successive solar cycles. The smoothed sunspot number is determined by a 13-month running mean of the Zurich monthly sunspot numbers (McKinnon, 1987). The month of the last three solar minima, as defined by the smoothed Zurich sunspot number, is listed in Table 1.

Cosmic Radiation Data. Figure 1 shows the monthly averages of the cosmic radiation intensity as measured by the Oulu, Finland neutron monitor between July 1964 and March 1989. This 9-NM-64 monitor was selected because of its stability over this 25-year period and because the 0.78 GV vertical cutoff rigidity at Oulu is below the atmospheric cutoff thereby allowing this detector to measure the complete spectrum of cosmic radiation above the atmospheric cutoff.

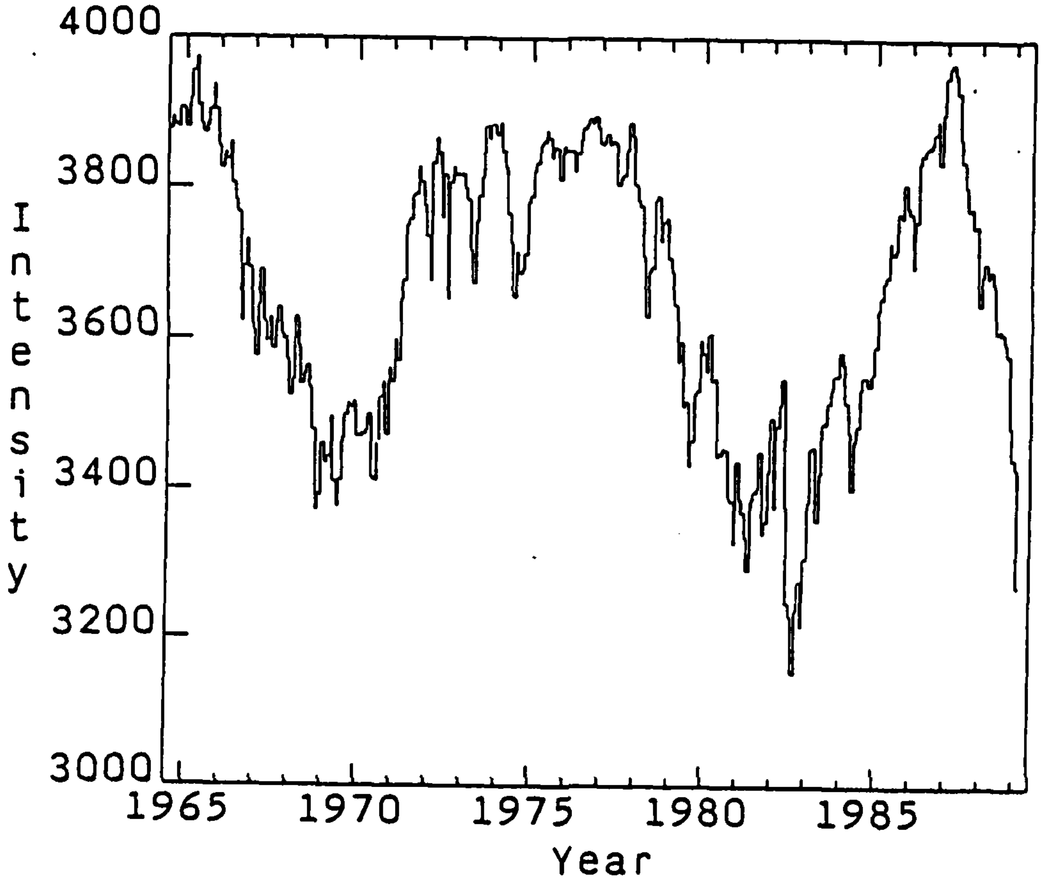

Figure 1. The cosmic ray intensity as observed by the Oulu, Finland neutron monitor for three successive solar minima.

TABLE 1. Sunspot minima and cosmic ray maxima for three solar minima.

Solar Cycle Minimum			Cosmic Ray Intensity Maximum (Oulu)		
Cycle	Month	SS* No.	Month	Intensity	ΔT**
19-20	Oct 64	9.6	May 65	3971.82	7
20-21	Jun 76	12.2	Nov 76	3895.81	5
21-22	Sep 86	12.3	Mar 87	3969.98	6

* Smoothed Sunspot Number
** Months between smoothed sunspot minimum and cosmic ray maximum

Table 1 lists the month of the maximum cosmic ray intensity between each of the last three solar cycles. The number of months between the sunspot minimum and the cosmic radiation intensity maximum is also given. As shown in Figure 1 and Table 1, the cosmic radiation intensity recorded in November 1976 was 1.9% lower than the intensity recorded in May 1965 and March 1987.

TABLE 2. Solar and Geomagnetic Activity Parameters for the Twelve Months Prior to and Including the Month of Maximum Cosmic Radiation Intensity

PARAMETER	SOLAR-MINIMA PERIODS BETWEEN CYCLES 19-20	20-21	21-22
Monthly Avg. Sunspot No.	10.8	11.9	12.3
Monthly Avg. Sunspot Areas	68.3	149.6	Not Available
Total No. Major Flares Using CFI	3	31	Not Available
Monthly Avg. aa indices	14.3	22.5	18.0

Solar and Geomagnetic Activity Parameters. Table 2 summarizes several solar and geomagnetic activity parameters for the 12-month period prior to and including the month of maximum cosmic radiation intensity. The values listed are the following:

Monthly Average Sunspot Number. The actual Zurich sunspot number for the 12-month period (McKinnon, 1987).

Monthly Average Sunspot Areas. These areas are from the Greenwich Royal Observatory Bulletins and are expressed in millionths of the sun's visible hemisphere. The Greenwich Observatory terminated this sunspot program in 1976, and although this work is being continued by a solar group in Hungary, values for the complete 21st solar cycle are not yet available.

Total Number of Major Flares using the Comprehensive Flare Index. "Major" flares as identified by the comprehensive flare index (CFI) (Dodson and Hedeman, 1971, 1975, 1981) were summed for the 12-month period. These flares are considered to have been well above average in either ionizing, H-alpha, or radio frequency radiation. Specifically, at least one of the following criteria must have been met for each of these flares:

a) Short wave fade (or SID) with an importance > 3;
b) H-alpha flare, importance > 3;
c) 10-cm flux, > 500×10^{-22} Wm^{-2} Hz^{-1};
d) Type II burst;
e) Type IV radio emission, duration > 10 minutes.

The derivation of these CFI values was not continued beyond 1980.

Monthly Average aa Indices. The geomagnetic aa index is a parameter describing the status of the geomagnetic field and hence is a measure of turbulent plasma in the immediate vicinity of the earth. This index is computed from the K index of two antipodal observatories; a full description of the index is given by Mayaud (1973). We have utilized the aa index as being representative of the geomagnetic activity at the earth; we consider this activity to be the product of the interaction between the earth's magnetic field and the turbulent plasma propagating by the earth. Cosmic ray transport in the heliosphere would be affected by perturbations in the plasma and interplanetary magnetic field.

Discussion. Unfortunately there is no unique measure of solar activity. The sunspot numbers are used as an activity parameter primarily because solar flares emanate from sunspot regions. However, the index is a quantized value where each region is counted as "10" and each spot is counted as "1" weighted for the penumbral and umbral structure. The sunspot areas are perhaps a better measure of active regions on the solar disk. From an inspection of Table 2, we note that while the monthly average sunspot numbers for each of the solar minima periods are essentially equal, the sunspot areas between the 20th and 21st cycles are twice the value as for the previous minimum. This is consistent with the factor of 10 increase in the number of "major" solar flares as defined by the CFI.

The monthly average geomagnetic aa index between the 20th and 21st cycles is also larger than for the other two solar minima periods. Although the aa index can be interpreted as a measure of turbulence at 1 AU which could be extended into the heliosphere, it represents disturbances primarily in the ecliptic plane. However, the 31 "major" flares from December 1975 through November 1976 occurred at latitudes ranging from 19 degrees North to 15 degrees South. If each of these flares ejected turbulent plasma into the interplanetary medium with a reasonable angular dimension of 20 degrees wide, these combined disturbances might have extended into the heliosphere with a cone of disturbance approximately 54 degrees in heliospheric latitude. Since these "major" flares occurred throughout this 12-month period, it appears reasonable to assume that the galactic cosmic rays might have been impeded somewhat during their transport in the heliosphere.

It is regrettable that there is no accurate measure of solar activity that can be unambiguously associated with the release of turbulence in the interplanetary medium. Even the proxy measurements used to infer solar activity are not always available for the periods for which galactic cosmic radiation has been continuously monitored. Solar flares would, perhaps, be a better indicator of solar activity; unfortunately, the solar flare data base is not homogeneous for the period of this study.

Conclusions. We have shown that the galactic cosmic radiation intensity as measured by a high latitude neutron monitor for three successive solar minima, was approximately 2% lower during the solar minimum period between the 20th and 21st solar cycles. We have also shown that the sun's solar activity, as inferred from proxy measurements, was considerably greater during the minimum between the 20th and 21st cycle (1976) than for either the previous solar minimum (1965) or the following solar minimum (1986). From these results we suggest that the turbulence in the interplanetary medium as established by excessive solar activity during the solar minimum period in 1976 impeded the transport of galactic cosmic radiation to 1 AU resulting in the attenuation of the galactic cosmic ray intensity.

Acknowledgment. We thank Drs. P.J. Tanskanen and H. Kananen for the Oulu, Finland neutron monitor data and L.C. Gentile for preparing Figure 1.

References

Dodson, H.W., and Hedeman, E.R.: 1971, UAG-14, WDC-A, Boulder, Co. USA.
Dodson, H.W., and Hedeman, E.R.: 1975, UAG-52, WDC-A, Boulder, Co. USA.
Dodson, H.W., and Hedeman, E.R.: 1981, UAG-80, WDC-A, Boulder, Co. USA.
Mayaud, P.N.: 1973, A Hundred Year Series of Geomagnetic Data 1868-1967, IAGA Bulletin No. 33, IUGG Publications Office, Paris.
McKinnon, J.A.: 1987, UAG-95, WDC-A, Boulder, Co. USA.